RESEARCH DEPARTMENT

Electrical correction for colour errors due to lack of far-red sensitivity in Plumbicon colour cameras

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SUMMARY

Lack of sensitivity in the long-wavelength reds causes errors of chrominance and luminance in a colour television camera employing plumbicon tubes. A simple non-linear matrix provides a useful degree of correction by adding to the red signal a proportion of the difference between the red and green signals when this difference is positive. Some extensions of this proposal are also suggested.

1. INTRODUCTION

The plumbicon is a photoconductive camera tube using lead oxide for the sensitive layer. Tubes now being produced lack sensitivity at wavelengths greater than about 625 nm and the response is virtually absent above 650 nm. This lack of sensitivity to part of the spectrum constitutes a departure from the correct red analysis curve, and errors of both luminance and chrominance result. The colour errors can sometimes be quite serious: for example, a deep red may appear much too dark or a magenta may appear much too blue. Nevertheless the advantages offered by the plumbicon in other respects are so great that this tube is likely to be widely used for colour television both in Europe and the U.S.A.

Errors due to incorrect analysis cannot be corrected perfectly by purely electrical means, since the information required for the correction is not available in the electrical signals. For example, two objects viewed by a colour camera could have exactly the same chrominance and luminance and appear identical to the eye, but have different reflection spectra; these could produce different errors due to lack of far-red sensitivity. Nevertheless, it would be highly advantageous to devise some means of correcting the errors approximately, even though exact correction is not possible.

Another report[1] describes a simple optical device for simulating the errors due to lack of far-red sensitivity. By looking at a large number of different objects through this device, it was possible to form some general opinion of the trend of the chrominance and luminance errors. It was in fact found that there was a useful degree of consistency between the errors observed in the portrayal of similar colours: for example, deep reds always tended to appear insufficiently luminous while less saturated reds tended to appear insufficiently saturated. Magentas tended to appear too blue, the effect being most noticeable in the case of magentas mid-way between red and blue on the colour triangle. There was a tendency towards slight colour errors in the reproduction of pinks, which appeared insufficiently saturated, and oranges, which appeared slightly too yellow.

The general result of the observations may be summed up by referring to the colour triangle shown in Fig. 1. There appeared to be no tendency to consistent errors in that part of the colour triangle on the green side of the blue-white-yellow line BWY. On the red side on this line, the errors tended to increase with distance from the line. Moreover the observations led to the impression that where an error occurred improvement would usually be effected by increasing the magnitude of the red separation signal. The degree of consistency appeared to warrant the development of an electronic circuit to provide some degree of correction.

2. PRINCIPLES

Fig. 2(*a*) shows a typical set of analysis curves for a colour camera. Ideally the analysis curves should contain negative and positive minor lobes in addition to the major lobes shown, but for practical reasons it has been usual to dispense with these. The effect of lack of far-red sensitivity in the plumbicon tube is indicated by the broken line. It is usual to adjust gains in a colour camera in such a way as to ensure correct reproduction of white, so that lack of sensitivity in the longer-wavelength red region is compensated for (in the case of white light) by enhanced sensitivity in the shorter-wavelength red region.

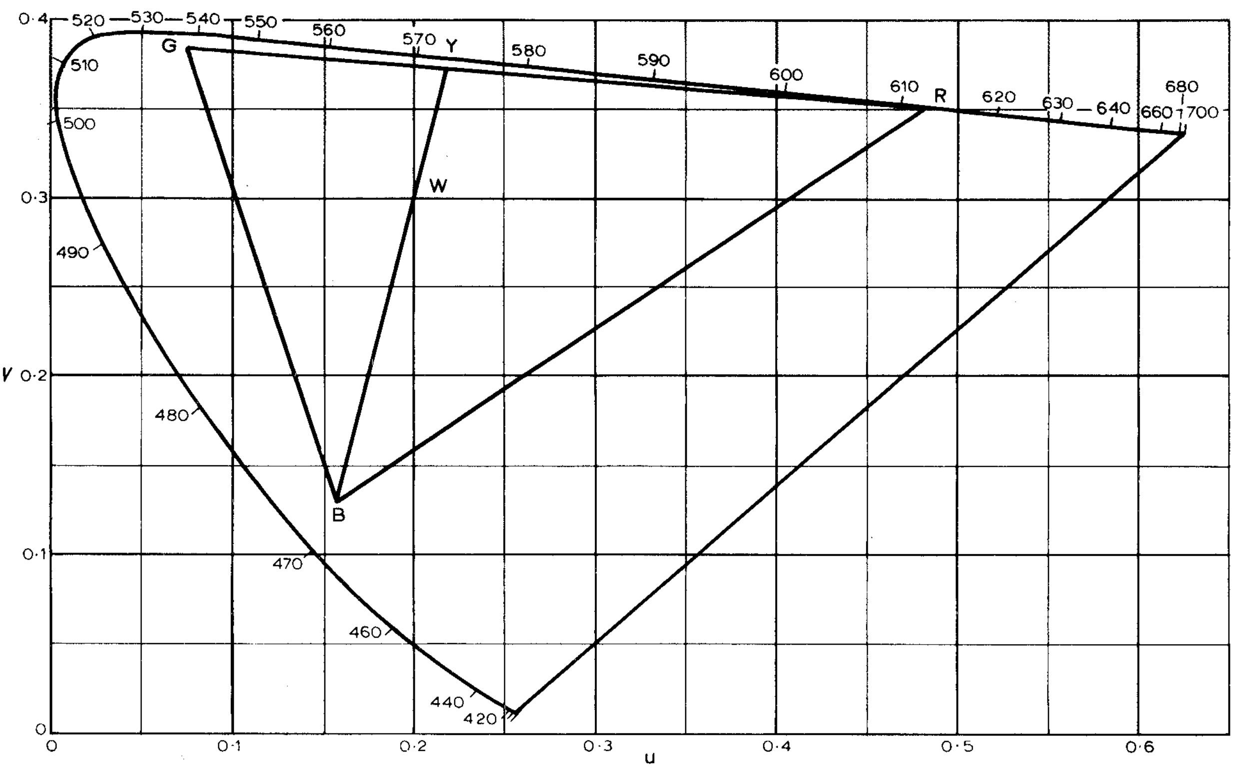


Fig. 1 - Colour triangle for the NTSC primaries

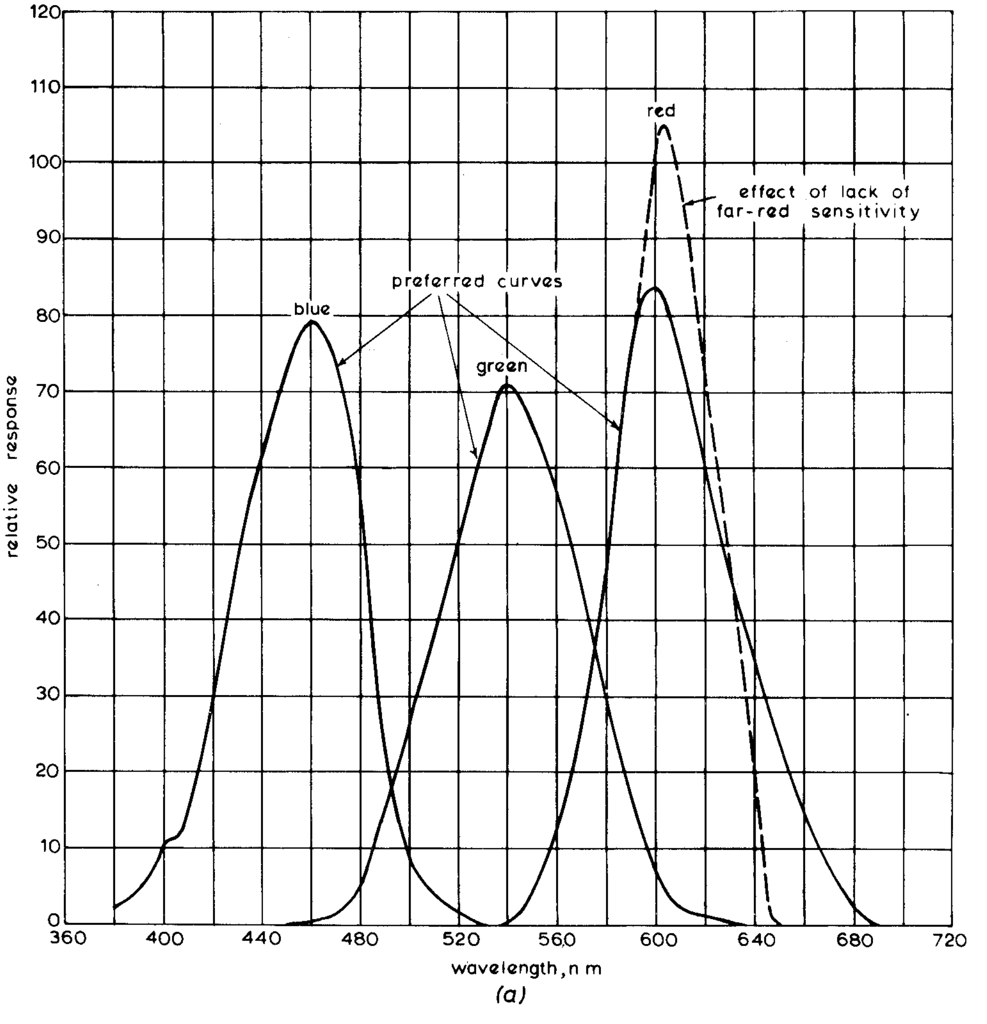
Suppose that the white light for which the gains have been adjusted is "equal-energy" white; this means that the energy in a given wavelength interval is independent of the mean wavelength of the interval. Then the areas under the full-line and broken-line red analysis curves shown in Fig. 2(*a*) must be identical. If, however, the spectrum of the light incident on the camera is not uniform, error will occur. For example, in the case of red light, one would expect the spectrum to fall off in amplitude towards the shorter wavelengths, so that the responses to this light corresponding to the red analysis curves shown will be different. Since the reflection spectra of most objects tend to be slowly varying functions of wavelength, any tendency towards greater energy density in the far red than in the shorter-wavelength red, will usually be accompanied by an excess of red light over green light. It is not therefore surprising that a lack of far-red sensitivity becomes more and more apparent as the excess of red over green increases.

It might be thought that errors would also occur in colours such as green and cyan in which green predominates over red, since it would appear reasonable to expect such red reflection as does exist to be mainly in the near-red region. In practice this is not generally true, because there is a general tendency towards a rise in reflection factor towards the longer wavelength reds, even when green predominates over red.* This tendency is illustrated in Fig. 2(*b*), which shows the reflection spectra of a series of coloured fabrics chosen as standard objects by the E.B.U. Ad-Hoc Colour Group for testing colour television systems.

* Pointed out by Mr. W.N. Sproson.

From the general conclusions arrived at by using the optical simulator as well as from consideration of the reflection spectra of coloured objects, it was concluded that improvement was likely to be effected by the use of a matrix which would add to the red signal a proportion of the difference between the red and green signals in such a manner as to enhance the red signal when this was predominant. However, in view of the fact that correction did not appear to be required in that half of the colour triangle where green predominates over red, it was decided to use a half-wave rectifier to suppress the difference signal (R′ - G′) whenever this was negative.

Fig. 3 shows a block diagram of the corrector as applied to a colour camera employing three plumbicons. In the case of a separate-luminance camera employing four plumbicons, a circuit such as that shown in Fig. 4 may be used in order to provide a separate correction of the luminance signal. However, if the separate-luminance tube is one like the image orthicon which is not deficient in far-red sensitivity, the circuit of Fig. 3 may be used to provide correction only to the red colouring signal.



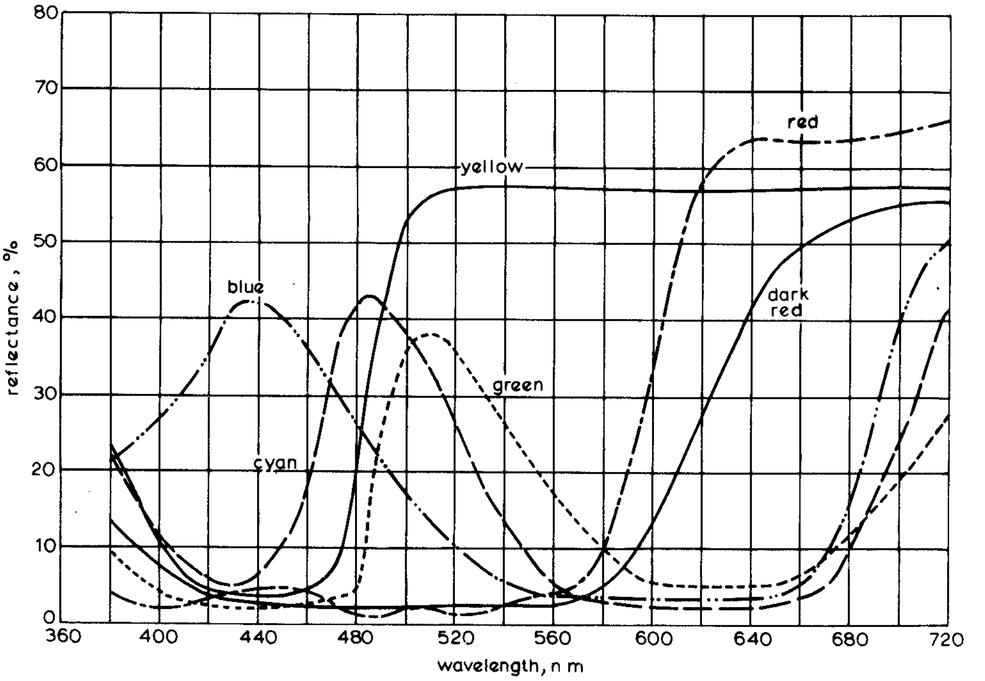


Fig. 2 - Analysis curves and reflection spectra
(*a*) Analysis curves (*b*) Reflection spectra of E.B.U. fabrics

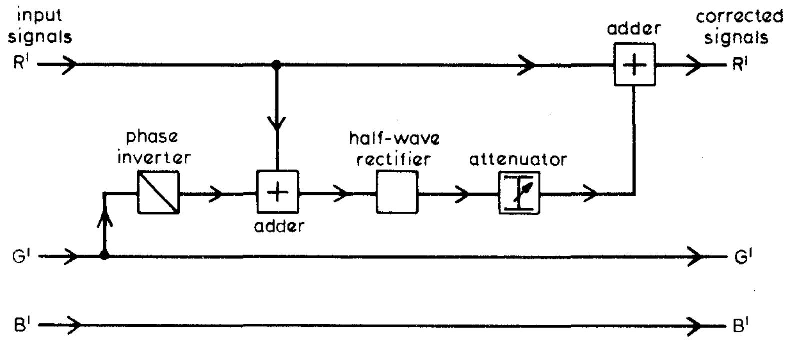


Fig. 3 - Corrector for three-tube camera

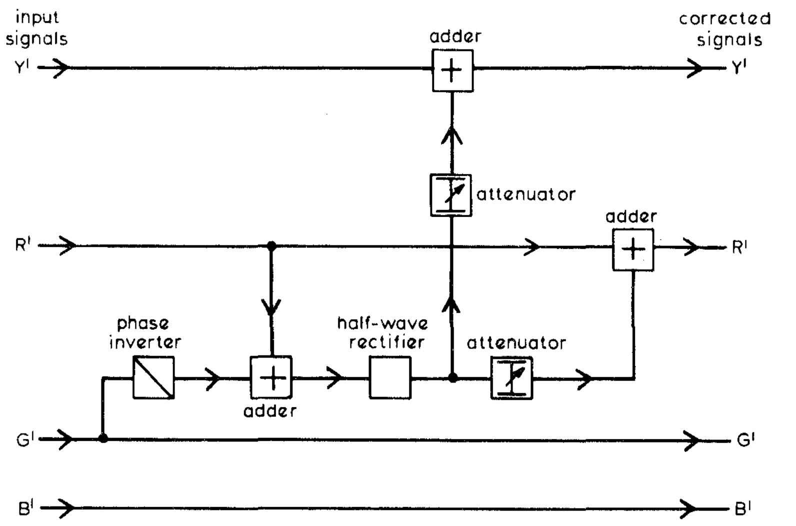


Fig. 4 - Corrector for four-plumbicon camera

3. EXPERIMENTAL

Fig. 5 shows the circuit of a simple device* corresponding to the schematic diagram of Fig. 3. For convenience, the unit was made self-contained with batteries. The correction signal is formed by subtracting the green signal from the red signal in TR1, TR2 and TR3. By suitable adjustment of potentials the correction signal is suppressed by cut-off of TR4 whenever the red input signal level is less than that of the green input signal. The clipped correction signal is then added to the red input signal in TR6.

At the time when this was completed, a plumbicon colour camera was not available and the unit was therefore connected to the output of a slide scanner; it appeared to produce the kind of effect that was required. It was arranged that the unit could be connected either to the linear (R, G, B) signals, or to the gamma-corrected (R', G', B') signals as shown in Fig. 3. No significant difference could be observed and it was therefore decided to use the unit for correcting gamma-corrected signals since these are less sensitive to mishandling and are readily available at the output of a camera channel.

As soon as an opportunity occurred, the device was tested (rather hurriedly) on a plumbicon colour camera in the colour studio of Philips Research Laboratories at Eindhoven. Philips' engineers had taken care when arranging the scene to find colours which revealed the plumbicon's lack of sensitivity in the far red. For example, there were some roses of an unusual pink which were portrayed almost as blue and some very deep red roses which appeared almost black.

The corrector produced a useful improvement in colour fidelity and no colours were seen to be made worse by it, although some must exist. Two disadvantages were, however, observed. In the first place, there was a significant increase in the noise level in those colours which were being improved. Moreover, when colour fringes were produced by deliberately misregistering the camera the red fringes were markedly accentuated.**

* Developed by Mr. H. Gregory.

** This was pointed out by Mr. S.L. Tan of Philips Organization, Eindhoven.

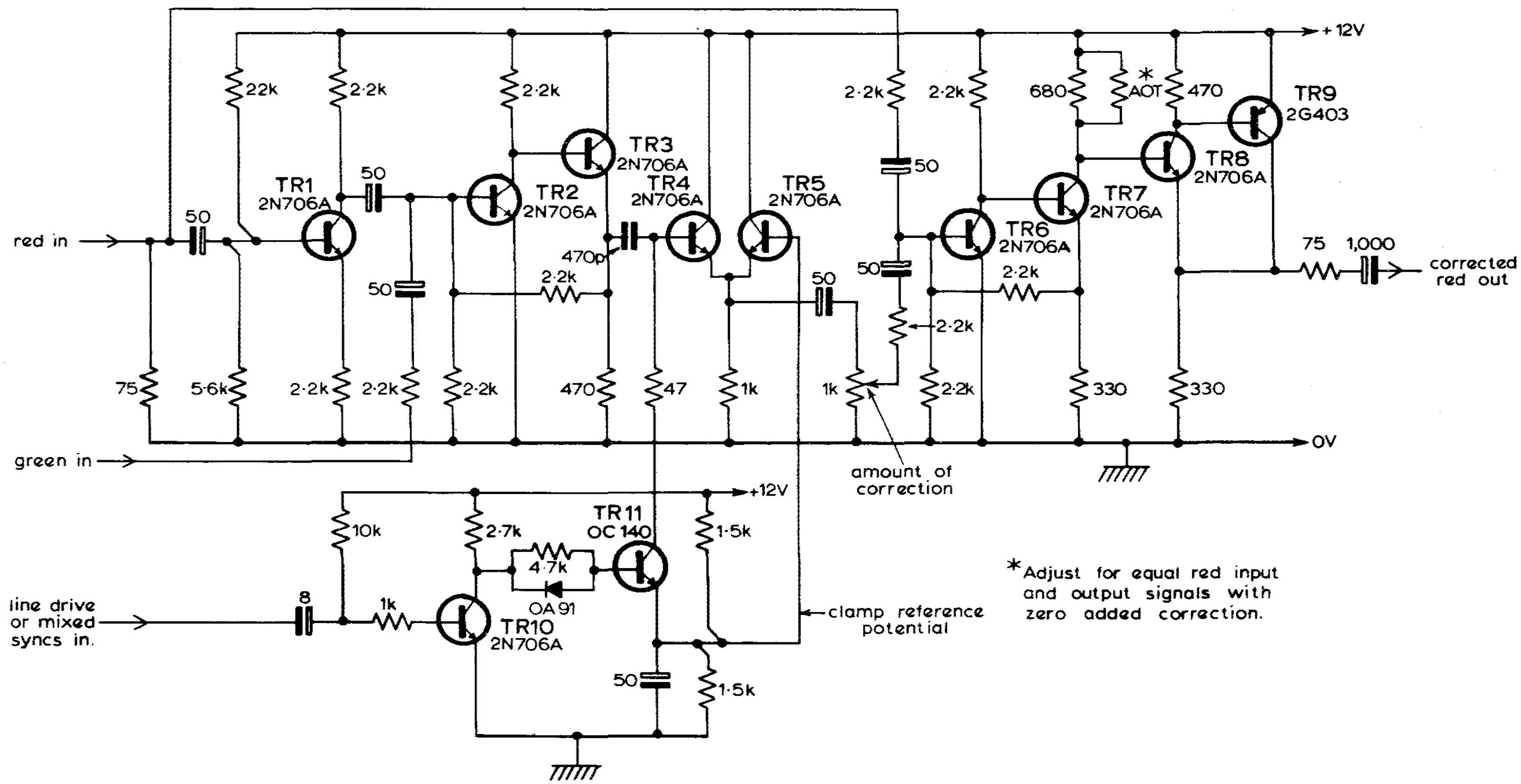


Fig. 5 - Experimental corrector for three-tube camera

4. CONCLUSIONS

The corrector shows sufficient promise to justify more careful tests when a plumbicon colour camera is available for a longer period. The increase in noise is its most serious disadvantage. It is likely that a useful improvement in this respect could be effected by restricting the bandwidth of the correcting signal, but this would increase the complexity of the corrector, since it would be necessary to use delays in all three channels to match the group delay of the filter. It might also be advantageous to include a limiter so as to avoid the production of a red signal of excessive amplitude. One or more limiters might act upon the red signal used for forming the correcting signal, the formed correcting signal and/or the corrected signal. This would reduce the accentuation of the effects of camera misregistration.

In the opinion of some observers cameras employing plumbicons tend to make flesh tones too purple, although calculations indicate that lack of far-red sensitivity should not have a significant effect of this kind. It does, however, seem that faces are sometimes made to look purplish by the use in picture tubes of a cold bluish white point (Illuminant C or even more blue) which is used because it makes both colour and monochrome pictures look crisper and cleaner. The linearity of the plumbicon facilitates an objective setting-up procedure using a grey scale, and this gives little scope for adjusting skin tones artistically. If purplish faces are found to present a problem in practice, the difficulty could be overcome by adding a small amount of correcting signal, reversed in sign, to the blue channel.

It has been shown[2] that a useful improvement in the colour fidelity of any colour camera may result from the use of a linear matrix which can subtract from each of the separation signals proportions of the others. This procedure effectively simulates the use of analysis curves having negative lobes. Recent work suggests that if lack of far-red sensitivity is taken into account while designing the matrix its effect will be less serious than when only the major positive lobes of the analysis curves are used. If so the proposed corrector, which is a non-linear matrix, may have less advantage to offer.

5. ACKNOWLEDGEMENTS

Thanks are due to Mr. S.L. Tan and other members of Philips Research Laboratories, Eindhoven, for assistance in testing the corrector with a plumbicon colour camera.

6. REFERENCES

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